Cape Canaveral beach view

3 What is a spaceport?

The operational concept of a spaceport can be defined incrementally by answering a series of questions.

- *What is the purpose of a spaceport?*
- *What is the spaceport environment?*
- *Who are the players at a spaceport?*
- *What functions does a spaceport perform?*
- *What are the key operating characteristics for a spaceport?*

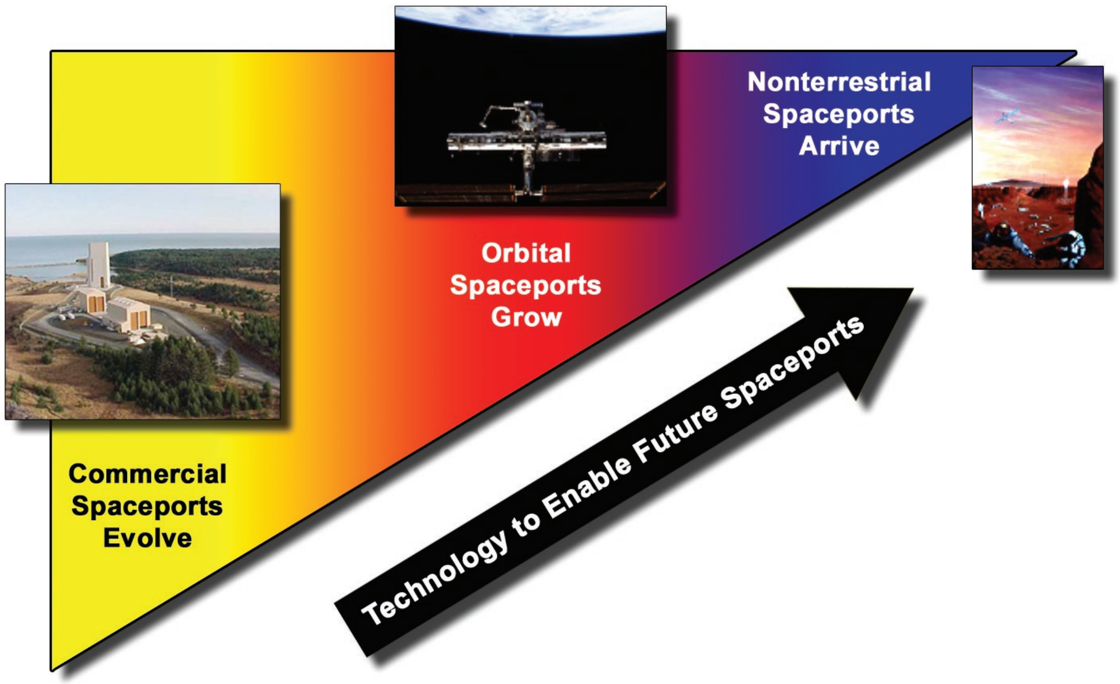

Figure 11. Spaceports perform similar functions, no matter where they are.

3.1 What is the purpose of a spaceport?

A spaceport provides the infrastructure where spaceflight vehicles depart, return, and prepare for their next flight.

A spaceport is the infrastructure at either the origin or destination of a spaceflight (see Figure 11). While in most cases the spaceport is a preexisting structure to receive an arriving spaceflight vehicle, for destinations at the boundary of exploration, the spaceflight vehicle may need to carry with it those components of a spaceport required to service and ready it for departure. A spaceport provides the capability to receive, process, and depart space payloads and vehicles. Between receiving and departing operations, the spaceflight vehicle might unload and load payload and crew and, if required, be serviced. The spaceport can provide an interface to other modes of transportation – air, land, and sea. At a spaceport, payloads and cargo are prepared for flight or reconfigured to continue the journey using another transportation mode.

The concept of spaceports has developed over the past several decades. In the late 1990s, the proposed VentureStar system capped a period of anticipated growth in demand for commercial reusable launch vehicles, stimulating renewed attention on spaceport development in the United States. A variety of reports and initiatives proposed solutions to spaceport development issues that are relevant to the approach outlined in this report.

As early as 1992, a National Research Council committee called for new "universal launch complexes" in Florida and California to provide shared launch site infrastructure by 2000.[5] The U.S. Air Force Space Command initiated an effort in 1998 to address industry issues related to the military space lift ranges. The resulting report defined a 10-year "national perspective" of divorcing space launch operations from test range infrastructure, leading to spaceports that are "operated like an airport and as a business."[6] At about the same time, the Air Force created a roadmap for a future air and space force. The roadmap report called for "transitioning national launch facilities to civilian operations with the Air Force as a tenant," or in other words, a spaceport.[7]

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5 J.G. Gavin, *From Earth to Orbit: An Assessment of Transportation Options*, 2003, <http://www.nap.edu/catalog/1976.html> (October 17, 2003).

6 Lt. Gen. Richard Henry (ret.), Range Integrated Product Team (IPT) Report, U.S. Air Force, November 16, 1998, <http://www.cctcorp.com/Range%20IPT%20v4-final.ppt> (October 17, 2003).

7 U.S. Air Force, *A Space Roadmap for the 21st Century Aerospace Force, November 1998.*

In 2000, a federal interagency working group headed by the White House Office of Science and Technology Policy and the National Security Council suggested creation of "spaceport authorities" to assume responsibility for launch base operations. The working group also called for investment in spaceport and range technology development.[8] That same year, a National Research Council committee completed a technical assessment of Air Force public safety methods and processes as recommended by the Range Integrated Product Team (IPT) in 1998. The committee's report includes brief descriptions of 15 studies conducted during that period related to U.S. space launch.[9]

The FAA's Commercial Space Transportation Advisory Committee (COMSTAC) released a working-group report focusing on high-priority issues related to spaceports in 2000.[10] During this period, several state-sponsored space organizations were developing business plans or bonding authorities for creating nonfederal spaceports. The Spaceport Florida Authority (now known as Florida Space Authority) commissioned a two-phase study in 2000 to baseline operations at the Eastern Range and proposed an "ideal" configuration for future spaceport activities. These state-sponsored spaceport organizations in California, Florida, and Virginia are now licensed and open for business in cooperation with the respective federal launch facilities in those states. A fourth spaceport has been licensed in Alaska that is not colocated with a federal range, and spaceport initiatives in Alabama, New Mexico, Oklahoma, Texas, and other states have established plans for hosting space launch operations. Existing and proposed spaceports outside the United States follow some of the same patterns. Operational sites in China, Japan, Russia, and South America compete with the U.S. spaceports for commercial launch business. Proposed spaceports in Brazil, India, South Africa, South Korea, Australia, and elsewhere are at various stages of development.

In 2001, a joint industry, government, and academia research team known as "Vision Spaceport" issued a report noting the need for a means to relate drivers of launch infrastructure to the resulting cost and flight rate capability.[11] Their work was based on a 10-point "vision of spaceport operations," partly inspired by the 1994 National Space Transportation Policy. The team also prepared a comprehensive spaceport technology catalog spanning propellant handling, launch assist, payloads, traffic management, range infrastructure, information systems, sensors and instrumentation, and command and control systems over a 25-year horizon, recommending investment of a modernized national spaceport infrastructure in high-payoff areas.[12] The team's earlier work products include a comprehensive spaceport definition document that details 12 key areas of spaceport functions.[13]

Most recently, a national commission noted the effects of aging U.S. space launch infrastructure and recommended its revitalization through an arrangement of federal spaceports, enhanced leasing authority, and privatization.[14]

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[8] White House, Office of Science and Technology Policy, *The Future Management and Use of U.S. Space Launch Bases and Ranges*, February 8, 2000, <http://www.ostp.gov/html/spaceranges.pdf> (October 20, 2003).

[9] National Academy of Sciences, Streamlining Space Launch Range Safety, 2000, <http://www.nap.edu/catalog/9790.html> (October 20, 2003)

[10] Commercial Space Transportation Advisory Committee, *Launch Operations and Support Working Group Report,* The Boeing Company, Seal Beach, California, May 31, 2000.

[11] Carey McCleskey, *Renewing America's Space Launch Infrastructure and Operations – Vision Spaceport,* (NASA internal publication) April 2000.

[12] Vision Spaceport Partnership, *Spaceport Concept and Technology Roadmapping – Investment Steps to Routine, Low Cost Spaceport Systems,* November 2000.

[13] Spaceport Synergy Team, *Vision Spaceport: Spaceport Module Definition Version 1.0,* September 2000, <http://www.cctcorp.com/technical%20papers/VSP-Module%20Definition%20Document.pdf> (October 20, 2003).

[14] R.S. Walker, *Final Report of the Commission on the Future of the United States Aerospace Industry,* November 18, 2002, <http://www.ita.doc.gov/aerospace/aerospacecommission> (October 17, 2003).

3.2 What is the spaceport environment?

The spaceport provides the essential infrastructure and related operations needed for space access to interface with the surrounding community and encompasses the facilities, organizations, and operations required to safely manage spaceflight.

Figure 12 illustrates the concept of the spaceport environment. The spaceport and range are integrated with the National Airspace System (NAS). The spaceport serves as a node in a multimodal transportation network. The community is a vital component of the spaceport environment.

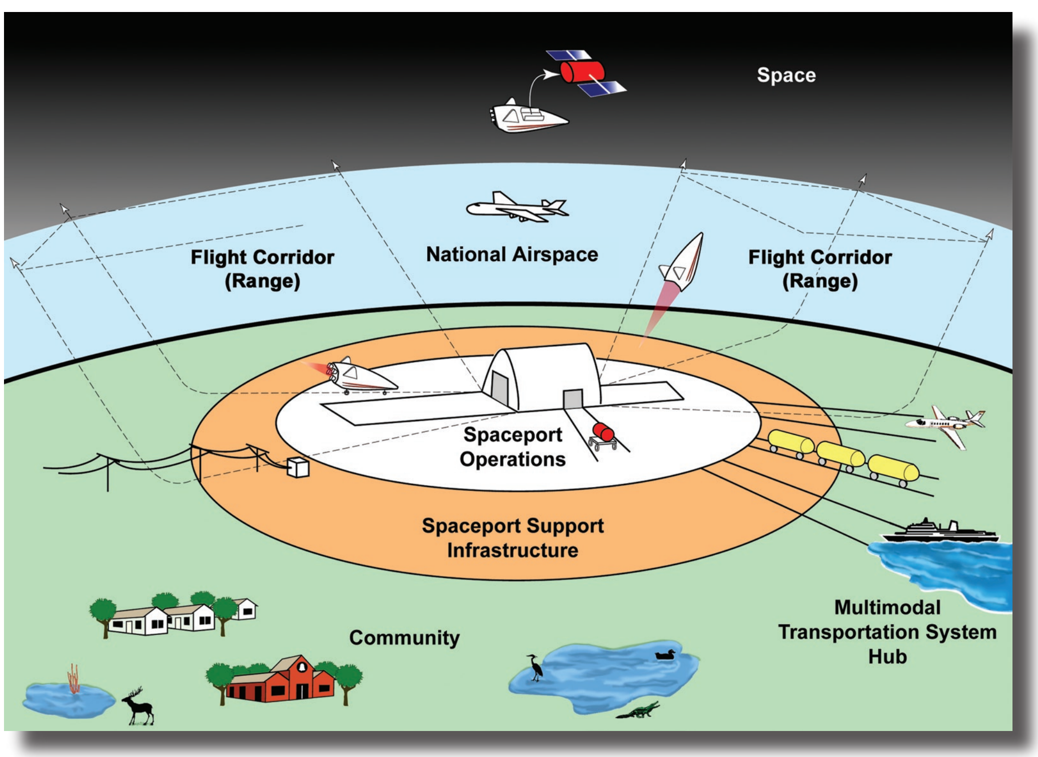


Figure 12. The spaceport environment

As in airport operations, it is important to distinguish between air-side (space-side) and land-side operations at a spaceport. The space side of the spaceport encompasses all direct functions required to ready a vehicle and payload for departure or, in some cases, return from space. The spaceport environment also includes land-side operations or spaceport-enabling operations, such as logistics, management of the spaceport operations, shared services, and public and community services.

Like airports, spaceports are complex businesses with functions that extend beyond the air-side operations. The community as well is an integral part of the spaceport environment. As major airports do today, spaceports can substantially benefit the economies of their communities.

3.3 Who are the players at a spaceport?

- *Spaceport Operator*
- *Launch Vehicle Operator*
- *Payload Customer*
- *Launch Vehicle Manufacturer*

A spaceport provides the essential infrastructure and related operations needed for space access. Space transportation operators in all sectors – military, civil, and commercial – can benefit from the economics of shared infrastructure and a flexible concept of operations that can affordably and safely accommodate a variety of payloads, vehicles, and flight management approaches. Similarly, spaceport operators can benefit from a shared global infrastructure that efficiently links their operations.

Spaceport technology investment can therefore be considered at several points along the space transportation "value chain."

Spaceport Operator

The spaceport operator provides the facilities and launch site infrastructure for recovery, postflight and preflight processing, and departure operations. Spaceport hosts may support a single user or accommodate multiple users. Technology investment for spaceport hosts will typically focus on the shared infrastructure available to spaceport users, benefiting a variety of stakeholders.

Launch Vehicle Operator

The vehicle operator acquires services and commodities from the spaceport host and may acquire vehicles from a vehicle manufacturer. The vehicle operator combines the spaceport services and products with its own unique launch site infrastructure to process and perform departure and return operations. Technological investment typically associated with ground operations of particular launch vehicle programs is a critical part of a comprehensive spaceport infrastructure technology portfolio.

Payload Customer

The payload, whether cargo or human, is the launch vehicle customer. Payload customers may contract with an operator to carry payloads from one spaceport to another or into orbit. Spaceport infrastructure investment must include payload processing technologies to address this crucial customer element.

Launch Vehicle Manufacturer

Launch vehicle manufacturers provide operators with vehicles. Today it is common for operators to manufacture their own vehicles, but emerging classes of transportation enterprises are exploring business plans focused on "spaceliner" operations using vehicles supplied by others. Manufacturers may choose launch site vehicle integration or assembly, giving them a stake in spaceport operations and further interest in spaceport technology development.

Taken together, the technological needs of these spaceport stakeholders span the entire space transportation enterprise. Advances in these key areas of launch site infrastructure technology are essential to achieve future robust space transportation systems.

Note that the identification of spaceport functions in 3.4 will not address *who* will perform those functions. It is critically important to understand that investment in launch site technology and infrastructure is important for all stakeholders – particularly spaceport hosts and spaceport users – regardless of existing notions of roles and responsibilities across the space transportation enterprise. Functions implemented and *who* performs them will be based on the types of space vehicles accommodated, the spaceport's management approach, the business model, and the concept of operations. Technology investment should be prioritized on innovations that will benefit spaceport stakeholders regardless of future business and operational models.

3.4 What functions does a spaceport perform?

- *Flight Element Operations*
- *Payload Element Operations*
- *Integrated Operations*
- *Flight and Ground Traffic Control and Safety Operations*
- *Enabling Operations*

Spaceport functions are organized into five operational areas. Each of these functions corresponds to a row depicted in Figure 13.

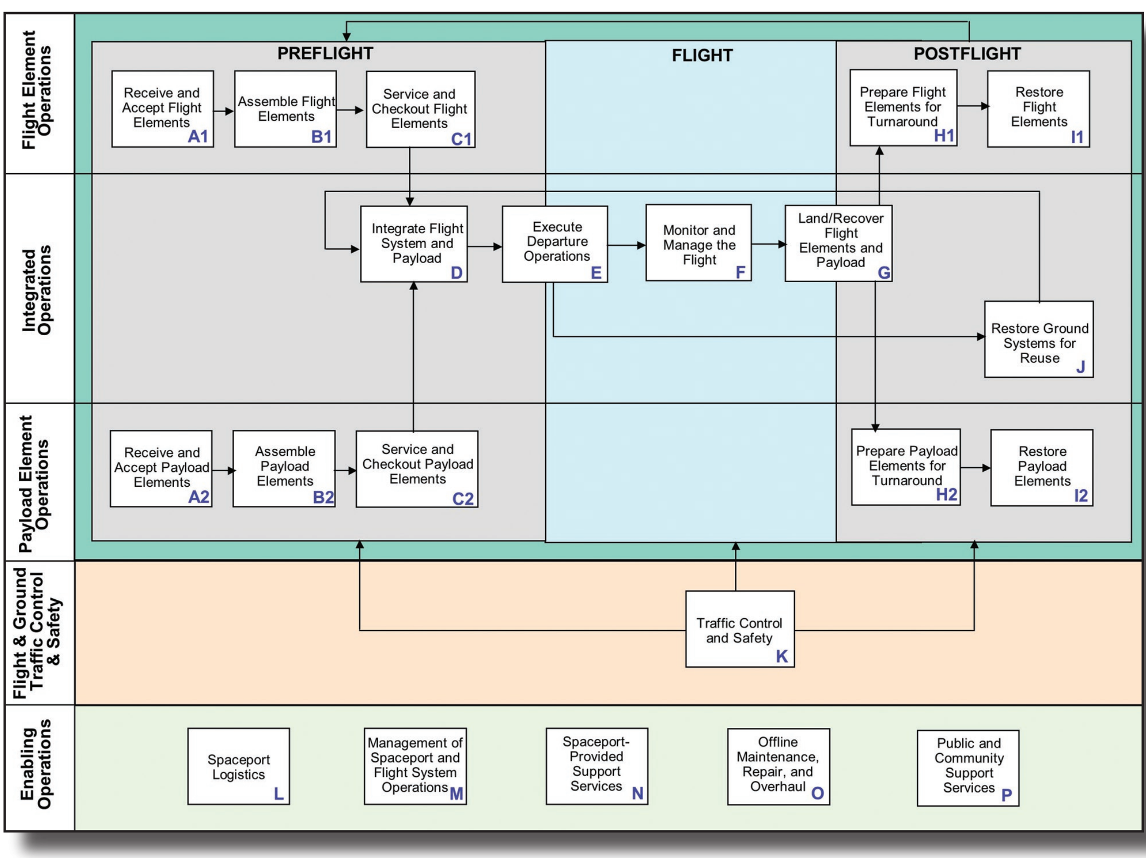


Figure 13. Generic spaceport operations model

Flight Element Operations

These include functions to prepare the space transportation vehicle elements for flight, including receiving/acceptance, final assembly of the vehicle elements, and the servicing of those elements. Postflight vehicle operations, including turnaround and maintenance, are encompassed.

Payload Element Operations

These include functions to assemble, integrate, and test payload elements in preparation for the mission and any postflight operations required. Payload element operations also include preparation of passengers/flight crew for their trip.

Integrated Operations

These include functions to integrate the flight vehicle and payload for departure. This includes in-flight support, landing/recovery, and deintegration. Restoration and ground support systems turnaround are included.

Flight and Ground Traffic Control and Safety Operations

These include functions to provide independent safety oversight for air and space transportation operations sharing global airspace and low Earth orbit.

Enabling Operations

Functions to support spaceport infrastructure, including logistics, management, support services, and maintenance. This area also includes the spaceport interface to the community.

This spaceport model identifies all possible basic functions relevant to spaceport operations, while recognizing that different spaceports may choose to implement only selected functions. The model approach identifies all functions performed at a spaceport without addressing *who* will perform the function. Functions implemented and *who* performs them will be based on the types of space vehicles accommodated, the spaceport's management approach, and the concept of operations.

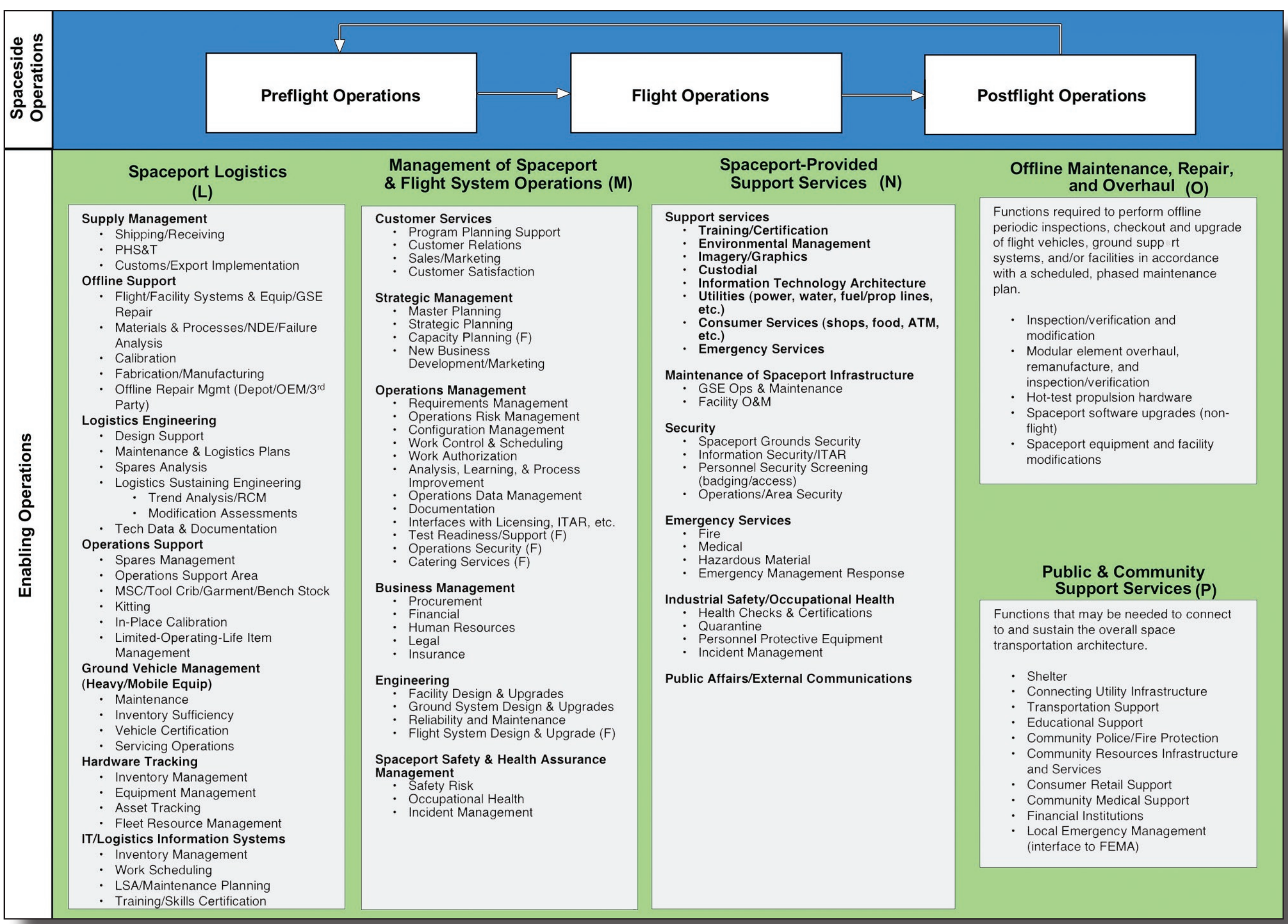


Figure 14. Generic spaceport-enabling operations – functions and subfunctions

The model is built in a functional breakdown structure. The functions and subfunctions (boxes A1 through P) are illustrated in Figure 13. The spaceport-enabling operations are expanded to their next level of detail in Figure 14. Subfunctional areas are further defined in Appendices D through H.

The definition of each box in the spaceport functional model can be found in Table 1. It is intended that this model can be applied to any vehicle/payload architecture.

Table 1. Definition of model components

ID	Subfunction Title	Subfunction Description
A1	Receive and Accept Flight Elements	Delivery of flight elements/systems/components to the spaceport from an external supplier or offsite depot for unpacking and acceptance.
A2	Receive and Accept Payload Elements	Delivery of payload or cargo element/systems/components to the spaceport from an external supplier or offsite depot for unpacking and acceptance.
B1	Assemble Flight Elements	Structurally assemble and mate components or segments of a flight element as received at the spaceport or launch area. Also transfer the assembled element to the flight vehicle integration point, if required.
B2	Assemble Payload Elements	Structurally assemble and mate components or segments of payload/cargo elements as received at the spaceport or launch area. Also transfer the assembled element to the flight vehicle integration point, if required.
C1	Service and Checkout Flight Elements	Prepare serviceable fluid commodities/systems and mechanical components requiring preflight adjustment and calibration and conduct electrical/electronic preflight preparations. Includes functional verification through physical assembly.
C2	Service and Checkout Payload Elements	Prepare serviceable fluid commodities/systems and mechanical components requiring preflight adjustment and calibration and conduct electrical/electronic preflight preparations. Includes functional verification through physical assembly.
D	Integrate Flight System and Payload	Structurally mate flight elements and payload/cargo elements into an integrated launch vehicle and mate to ground support systems. Transfers the mated vehicle to the launch point, if required by the concept.
E	Execute Departure Operations	Provide final preparation, servicing, and payload and/or crew ingress and launch the flight vehicle into space. Includes the postlaunch securing and refurbishment of the facilities and equipment at the launch point.
F	Monitor and Manage the Flight	Control mated vehicle flight, staged element flight to space, and element return, if required. Does not include in-space transportation operations (i.e., “control the [space] mission”).
G	Land/Recover Flight Elements and Payload	Arrival or return of a flight element and/or cargo/payload elements during the course of a space flight. The arrival may be the trip back from space, perhaps a boost or assist stage returning, or a return-to-launch-site abort.
H1	Prepare Flight Elements for Turnaround or Disposal	Postflight disassembly of flight element segments for refurbishment/remanufacture. Also includes planned removal of limited-life items and major components that may require offline preflight activities.
H2	Prepare Payload Elements for Turnaround or Disposal	Postflight disassembly of cargo/payload elements segments for restoration and refurbishment. Includes offload of experiments, removal of racks, breakdown of segments, etc.
I1	Restore Flight Elements	Perform troubleshooting and repair and replacement of failed or worn parts of flight vehicle elements. Includes element remanufacturing and off-manifest phased-maintenance actions, such as vehicle or vehicle element.
I2	Restore Payload Elements	Perform troubleshooting, repair, and replacement of failed or worn parts of payload/cargo element and reconfigure for next flight.
J	Restore Ground Systems for Reuse	Restore ground systems, such as commodity replenishment, maintenance, and refurbishment.
K	Traffic Control and Safety	Monitor and separate space and air traffic, ensure safe ground movements within the spaceport, and protect the public and spaceport assets.
L	Spaceport Logistics	Plan, implement, and control the flow and storage of goods, services, and related information from the point of origin (vendor) to the point of consumption (spaceport flight-line operations).
M	Management of Spaceport and Flight System Operations	Host services needed to plan, manage, and control the operation of the spaceport and space transportation assets, as well as all elements of the ground infrastructure.
N	Spaceport-Provided Support Services	Indirect services in support of on-vehicle operations. These may include a variety of host services needed to support flight production.
O	Offline Maintenance, Repair, and Overhaul	Perform offline periodic inspections; checkout and upgrade of flight vehicles and ground support systems and common spaceport infrastructure in accordance with a scheduled phased maintenance plan.
P	Public and Community Support Services	Connect the surrounding community with spaceport operations to sustain the overall space transportation architecture and infrastructure.

3.5 What are the key operating characteristics for a spaceport?

The envisioned missions, spaceport locations, desired origins/destinations, and connections will demand certain key characteristics of future spaceports.

- *Interoperability*
- *Ease of Use*
- *Flexibility*
- *Safety/Environmental Protection*
- *Multiple and Concurrent Operations*

The long-term vision is to have airportlike spaceport operations. Airportlike refers to high flight rates and the accommodation of multiple vehicle architectures without significant reconfiguration of the infrastructure after each mission. The transition of a space vehicle through the National Airspace System will be seamlessly integrated, causing minimal disruption in the current air traffic control system. The turnaround times of the vehicles will be on the order of hours.

Interoperability

To achieve airportlike operations, the spaceport must employ standardized interfaces to the spaceflight vehicle, much like today's airports. An aircraft can land at almost any airport around the world because of some level of standardization in the airport infrastructure. Spaceports of the future will incorporate standards between spaceports around the country and offsite customer locations, and even internationally to support operations virtually anywhere on Earth.

Ease of Use

All operations performed at the spaceport must strive to reduce the specialty skills required for preparing a spaceflight vehicle for its mission. This can be accomplished by implementing consistent and easy-to-use interfaces that are simple to assembly, thus requiring less time for processing.

Flexibility

Spaceports in the future must be able to service multiple types of spaceflight vehicles. The spaceport must be capable of easily adapting to new vehicles and payloads and be able to adapt to and accommodate new or changing requirements or technologies.

Evolvability

Spaceports must be adaptable over time to accommodate any spaceflight vehicle architecture. The spaceport infrastructure must be responsive to upgrades and enable incremental transition from the current and planned spaceport architecture to the next-generation architecture without impacting the spaceport operations.

Safety

The spaceport must ensure safe operations by minimizing risk to people (spaceflight crew, public, and spaceport workforce), property (spaceport infrastructure, flight hardware, and surrounding community), and the local ecosystem. Cost-effective safety enhancements can be accomplished through enhanced vehicle and spaceport design.

Multiple and Concurrent Operations

Today, departure operations at a spaceport are primarily serial, requiring all other operations to hold until the flight is on its way. Spaceports of the future will have the capability to support multiple operations and perform them concurrently without impacting each other.

These operating characteristics will allow spaceports to accommodate any type of vehicle, payload, or commercial concept and help the spaceport deliver the desired outcomes to the space industry, as shown in Figure 15.

The overall spaceport system capability goals are identified in Figure 16. More detailed capabilities defined by spaceport function are provided in Appendix D.

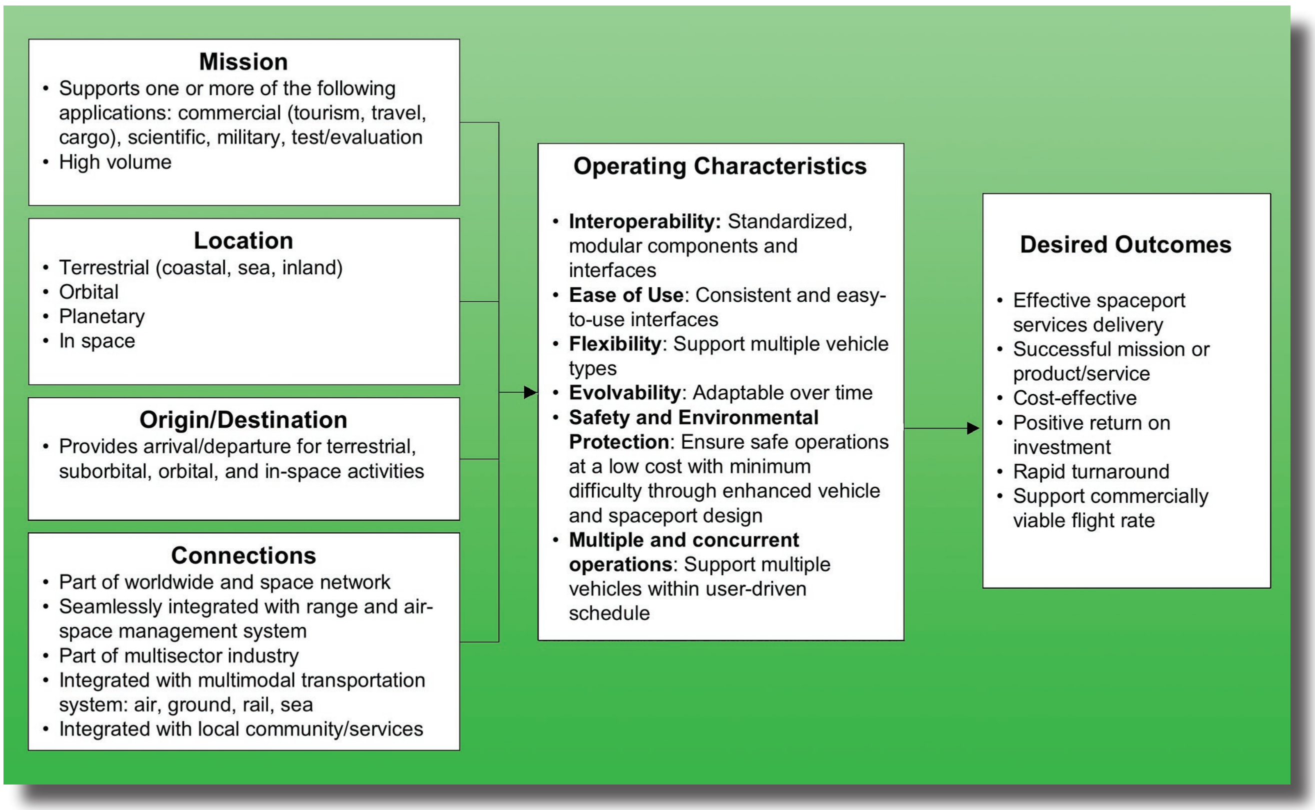
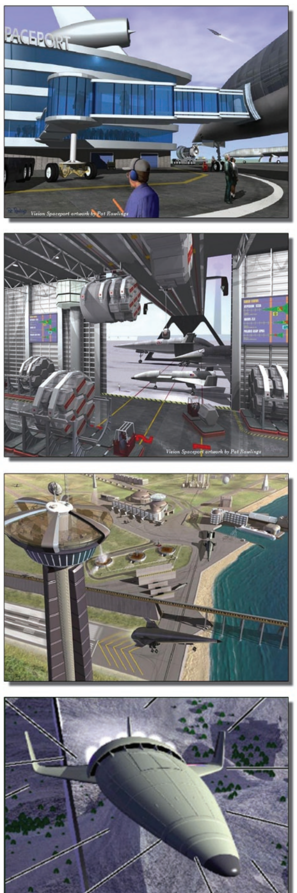


Figure 15. Characteristics of an ideal spaceport



Near-Term:

- High flight rate of a single architecture
- Standardized servicing ports and interfaces
- Standard payload carrier
- Common/universal lifting GSE
- Control software development based on abstract interfaces
- Control software for automatic propellant loading
- Enhanced remote sensing for vehicle safety after landing
- Paperless integrated logistics systems
- Centralized data repository – integrated databases
- Enhanced information/ communication architecture
- Integrated emergency services

Mid-Term:

- Multiple vehicles from common spaceport infrastructure
- Common standards between vehicle and spaceport
- Containerized payloads
- Robotic support for lifting operations
- Spaceport interfaces recognize flight system connected
- Automated servicing operations
- Automated safing/ reconfiguration of vehicle and payload after flight
- Automated and integrated paperless logistics system
- Automatic interactive scheduling of flight vehicle, ground support facilities, and support logistics
- Integrated communication system linking several spaceports
- Semiautonomous surveillance

Far-Term:

- Airportlike operations
- Minimal servicing with self-diagnosis and autonomous repair
- Piggyback payloads – self-sufficient; noninvasive to vehicle
- Minimal facility/vehicle interfaces
- On-demand propellant loading operations
- Autonomous safing/ reconfiguration after landing
- Automated paperless supply chain management integrated with equipment integrated health management
- Business systems and processes integrated into one data management system
- Autonomous, adaptive self-training scheduling system for flight vehicle, ground facilities, and support infrastructure
- Global connectivity to spaceports
- Autonomous surveillance

Figure 16. Overall spaceport system capabilities goals

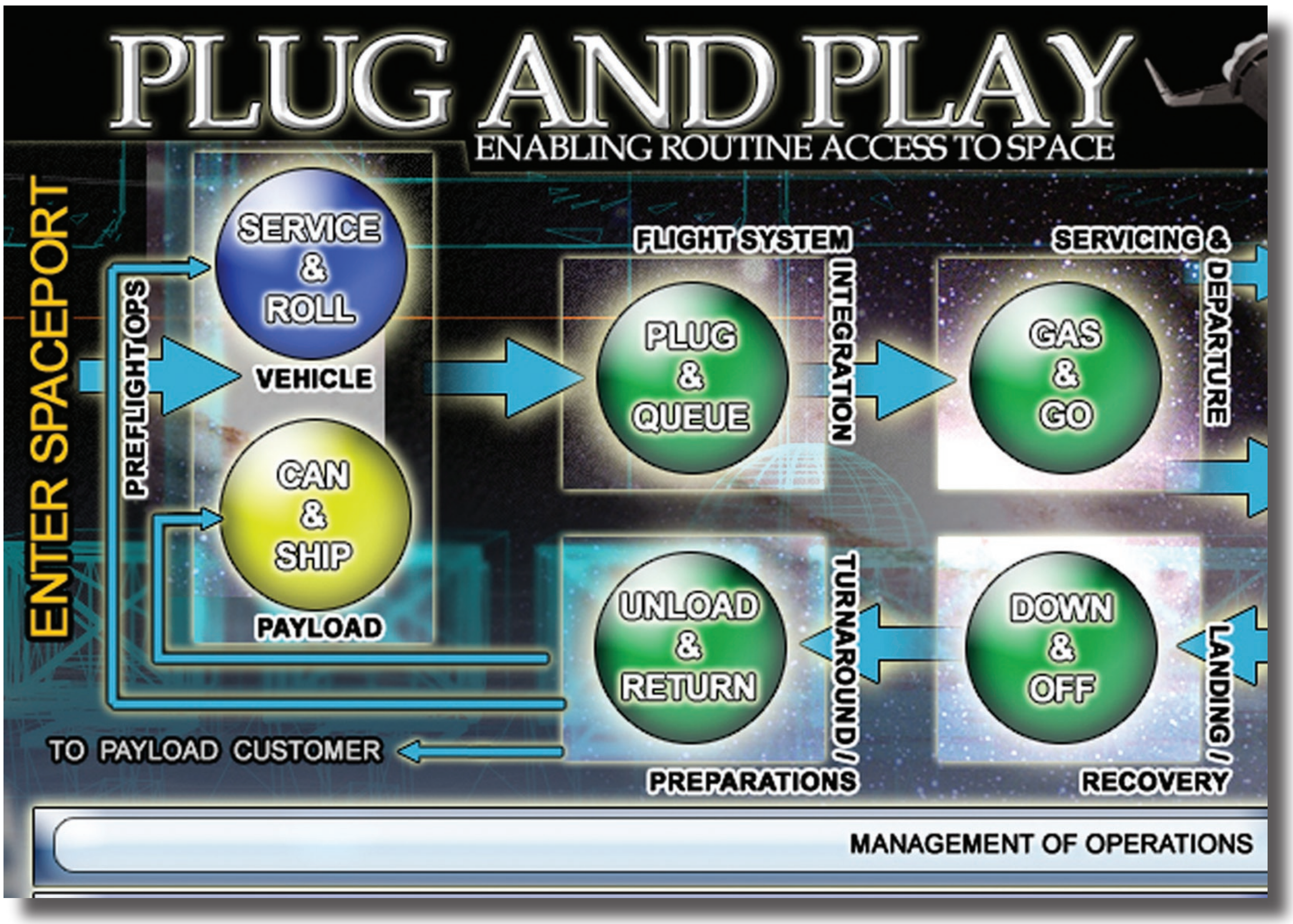


Figure 17. Plug & Play vision of spaceport operations